

Book Review

Behavioral Pharmacology Today: A Review of *Advances in Behavioral Pharmacology*, Vol. 4, and *Behavioral Pharmacology: The Current Status*

Marc N. Branch
University of Florida

The origin of behavioral pharmacology as an identifiable discipline can be traced to P. B. Dews' 1955 paper in which he described experiments with sodium pentobarbital (Dews, 1955). Dews trained food-deprived pigeons to peck a response key under either a fixed-ratio (FR) 50 or fixed-interval (FI) 15-min schedule of food presentation. Subsequently, he examined effects of several doses of pentobarbital by injecting the drug prior to selected sessions. He discovered that the effects of the drug on rate of pecking depended on the schedule of reinforcement. Specifically, doses of the drug that produced substantial decreases in responding under the FI schedule could result in increases in responding under the FR schedule. Two features of Dews' work can be viewed as having been unique at the time it was published. First, he provided a powerful demonstration of the importance of environmental, or behavioral, variables in the determination of behavioral effects of drugs. In his experiments, he showed that performances that were topographically similar (key pecking) and occurring for the same reason (food reinforcement) were differentially sensitive to the effects of a drug, and that this differential sensitivity was due to

seemingly subtle environmental variables (the reinforcement schedules). Second, he took advantage of procedures developed in the experimental analysis of behavior that allowed him to establish reproducible behavioral processes in individual subjects. Such techniques allowed him to examine drug effects, across a range of doses, in individual organisms.

These two aspects of Dews' work, the emphasis on environmental determination of drug effects and the use of behavioral control techniques derived from the experimental analysis of behavior, defined a new discipline, behavioral pharmacology. Prior to his work, the study of behavioral effects of drugs had focused mainly on topographically based or motivationally based accounts (e.g., the effects of drugs on "aggression" or on "fear" or "anxiety"), and most work had involved the study of relatively large groups of subjects. The previous work, however, had revealed that drugs can have different effects on different behavioral activities. Dews' work pointed to a new field of research endeavor by outlining more clearly a major implication of the earlier work, an implication that can be derived syllogistically:

- Premise 1: Different behavioral activities can be affected differently by a drug (an empirically validated premise).
- Premise 2: Different environments (including, of course, differing contingencies of reinforcement) can yield different behavioral activities (another empirically validated premise).

Complete citations are: Thompson, T., Dews, P. B., and Barrett, J. E. (Eds.). (1984). *Advances in Behavioral Pharmacology*, Vol. 4. New York: Academic Press; Seiden, L. S., and Balster, R. L. (Eds.). (1985). *Behavioral Pharmacology: The Current Status*. New York, Alan R. Liss. The author wishes to thank Ms. Geraldine Lennon for her expert secretarial assistance. Reprints may be obtained by writing to the author at the Psychology Department, University of Florida, Gainesville, FL 32611.

Conclusion: Different environments can result in different drug effects.

Thus, the task for the new research field was to determine how environments modify behavioral effects of drugs, for which the use of procedures from the experimental analysis of behavior was viewed as best suited for accomplishing this task.

More than thirty years have passed since Dew's pioneering research, so it may be appropriate to examine and evaluate what has happened to the scientific discipline that emerged following his seminal work. An opportunity to do that is provided by the recent publication of two compendia of contemporary work by behavioral pharmacologists, *Advances in Behavioral Pharmacology* (v. 4) and *Behavioral Pharmacology: The Current Status* (hereinafter called *Advances* and *Current Status*, respectively). The two books are both edited volumes, with chapters contributed by noted researchers in the field of behavioral pharmacology. *Advances* is the fourth volume in a series that began in 1977, whereas *Current Status* is a collection of papers from a series of symposia, jointly sponsored by Division 28 (Psychopharmacology) of the American Psychological Association and the American Society for Pharmacology and Experimental Therapeutics, at the 68th annual meeting of the Federation of American Societies for Experimental Biology.

Because of their divergent origins, the two collections differ, with fewer contributions appearing in *Advances* (7) than in *Current Status* (32). Those in *Advances* tend to be longer, more comprehensive, and more integrative than those in *Current Status*. Despite these differences in format, the two volumes provide a representative sample of current research in behavioral pharmacology and thus provide a basis for examining the state to which the field has evolved. In the review to follow, special emphasis will be given to identifying the extent to which the two original distinguishing characteristics of the field, emphasis on environmental/behavioral determination and

employment of behavior-analysis based procedures, are manifested.

A SHORT HISTORY

Before discussing the current state of the field, however, it may be helpful to describe briefly the history that has led behavioral pharmacology to its present position (more thorough descriptions can be obtained in Branch, 1984 and Pickens, 1977). The discipline of behavioral pharmacology grew rapidly through the 1960s. Most of the research conducted during that period was consistent with the two themes present in Dews' original work. That is, procedures developed in the experimental analysis of behavior were used to demonstrate the role of the environment in the determination of drug effects. Attention was also given during this time to attempts at analyzing drug effects in terms of behavioral processes. For example, Dews and Morse (1961) argued that chlorpromazine's selective effect on discriminated avoidance performance could be interpreted as a special case of the drug's influence on exteroceptive stimulus control in general. An especially promising behaviorally based interpretation was the concept of rate dependency. This concept, which implies that effects of a drug on response rate can be predicted from response rate under non-drug conditions, was seen to have wide applicability (Kelleher & Morse, 1968) and came to play a dominant interpretive role in behavioral pharmacology.

Techniques were also developed during the 1960s that allowed the study of drug self-administration in animal subjects (for reviews see Goldberg, 1976; Johanson, 1978; Schuster & Thompson, 1969). Surgical procedures were developed to implant chronically indwelling venous catheters in a way that subsequently left the animal with reasonable freedom of movement. Animals thus prepared could be exposed to operant conditioning procedures wherein intravenous drug administration could be programmed as a consequence of behavior (cf. Weeks, 1962). The discovery that drugs that are self-administered by humans also can serve as reinforcers for

nonhumans led to increased study of drugs as reinforcers.

The decade from 1960 to 1970, then, was characterized by research that was consistent with the two themes present in Dews' early research. Near the end of this period, the field's first textbook was published (Thompson & Schuster, 1968), and it too emphasized both the analysis of drug effects in behavioral/environmental terms and the utilization of techniques derived from the experimental analysis of behavior. Over the next decade, however, the picture was altered.

Three developments can be viewed as leading to the changes that occurred. First, employment of behavioral interpretations of drug effects had not been particularly successful, and even the widely accepted principle of rate-dependency began to be viewed as relatively restricted in application (e.g., Barrett, 1976; McKearney, 1974) or even wrong in some cases (e.g., Branch & Gollub, 1974; Gonzalez & Byrd, 1977). Second, there was rapid growth in research on drugs as discriminative stimuli. In 1970, no papers examining the discriminative properties of drugs were published, but by 1980, the rate was nearly 50 papers per year, and climbing (Stolerman & Shine, 1985). Third, following the development of stereospecific receptor binding techniques came a truly explosive growth in knowledge concerning drug receptors in the central nervous system (see Snyder, 1984 for a review).

The developments in neuropharmacology provided a reductionistic explanatory base for interpretation of experiments in which drugs are compared, and students of the discriminative properties of drugs were quick to make use of it. Drugs that exert similar discriminative control can be hypothesized to act at the same receptor sites in the brain. Such interpretations were frequently fruitful (e.g., France, Jacobsen, & Woods, 1984; Young & Stephens, 1984), and these successes led researchers examining other drug-behavior interactions to turn to these kinds of interpretations. In the 1970s, then, much of behavioral pharmacology turned in a new direction. The type of behavioral-control techniques stayed the same,

but the questions asked and interpretations offered became decidedly more pharmacological and less behavioral.

A FRAMEWORK

As we move into the 1980s, the two books under review here allow us to see if, and to what extent, the change in interpretive focus has continued. To aid in this examination, the framework provided by the two main themes exemplified in Dews' work must be expanded by addition of a third category—research in which behavior-analytic techniques are employed, but where the focus is on pharmacological or physiological interpretations. That is, most of the material in the contributed chapters in the two volumes can be characterized as exhibiting one or more of three rather than two, emphases: (a) an emphasis on environmental determination of drug effects, (b) an emphasis on drug effects on behavioral processes via the utilization of techniques from the experimental analysis of behavior, and (c) an emphasis on pharmacological (usually receptor-based) or physiological interpretation of drug effects on behavior engendered via behavior-analytic methods.

The two volumes differ with respect to the relative distribution of these three types of chapters in ways that are consistent with the stated goals of each. As noted in the preface to the first volume of the *Advances* series (Thompson & Dews, 1977), "Neurochemical and neurophysiological actions of drugs generally fall outside the domain intended to be included in this series The analysis will be limited to *behavioral* actions of drugs and so will generally not include investigations at other levels of analysis" (p. ix). This may be contrasted to the prefatory remarks in *Current Status* to the effect that "The behavior of the animal is the complex *physiological* (italics mine) response that results from neurochemical and neurophysiological responses occurring in the central nervous system" (p. xiii). Consistent with these differences in aims, *Advances* contains no chapters in which the primary emphasis is on reductionistic explanations.

Four "Outliers"

Four chapters in *Current Status* do not fall into any of the three categories listed above. The first of these, by Leander, deals with effects on drinking and urinary output of drugs that are active at putative kappa opioid receptors. The second, by Bunney, Chiodo, Grace, and Schenck, does not involve the study of behavior directly, but instead focuses on effects of acute and chronic administration of antipsychotic drugs on midbrain neurons that contain dopamine. The third paper in the group is by Creese, and consists primarily of excellent descriptions of radioligand receptor binding techniques and their interpretation, and secondarily of a receptor-based account of psychosis. The fourth and last paper that does not fit in any of the three categories is by Lucki and Frazer who report on effects of repeated administration of antidepressant drugs on behavior thought to be associated with serotonin receptors. The behavior studied consists of observationally defined topographies in untrained subjects. Four of the contributions to *Current Status*, then, do not exemplify either of the two major themes emanating from Dews' early work. Behavior analytic control techniques are not involved and no emphasis is given to environmental determination. Instead, primary emphasis is on receptor-based accounts of effects of drugs that are used for their behavioral actions. These four papers may indicate, therefore, a broadening of what constitutes behavioral pharmacology. The remaining 35 chapters, however, can be fit comfortably into the three categories outlined above, and thus can be construed as examples of research that follow, at least partly, the tradition of Dews.

Environmental Modification of Drug Effects

Several of the chapters in both books deal with environmental determination of drug effects. Barrett, in *Current Status*, reviews his provocative and exciting work illustrating how response rate, type of consequence, behavioral context, behav-

ioral history, drug history, and even specific drug-environment history all can function to alter dramatically (even qualitatively) a drug's behavioral effects. His work serves to emphasize that "... in contrast to the relatively static impact of the ecological environment, the behavioral environment is dynamic and responsive; it both influences and is influenced by behavior" (p. 7).

Three other chapters that are concerned with environmental effects also contain material that falls in one of the other two categories listed above. Chapters in *Current Status* by Dykstra, on analgesia produced by opioids, and by Kilbey and Sannerud, on sensitization to effects of psychomotor stimulants, both include material concerning pharmacological or physiological interpretations as well as material illustrating the importance of environmental variables in determining behavioral drug effects. Balster's review in *Current Status* of tolerance and dependence is unique in that it can be classified as exemplifying the first two categories. He presents data that illustrate the use of behavior-analytic techniques to study the phenomena of drug tolerance and drug dependence, as well as information revealing how environmental factors can influence these phenomena. His chapter is noteworthy in another regard. It presents one of the many mysteries that illustrate both how much there is left to be learned and the importance of dynamic behavior-environment interactions. Specifically, he reports that when phencyclidine is given to monkeys response independently, in amounts that the monkeys self-administer when the drug is available response dependently, severe toxic reactions develop that are not observed under the self-administration condition. Thus, arranging the contingency for self-administration apparently reduces the toxicity of the drug.

Drug Self-Administration

Both *Advances* and *Current Status* show that the study of drug self-administration continues to flourish, with elev-

en chapters devoted to the topic. Several of the contributions in this domain present analyses of environmental determination of drug action. Of course, from one point of view, any self-administration study reveals behavioral determination of a drug's effects because the drug is serving as a reinforcer. Several papers, however, reveal not only this fact, but also focus on environmental modification of drug taking. Chapters by Falk (in *Current Status*) and by Carroll and Meisch (in *Advances*), for example, detail how food-reinforcement scheduling arrangements or food deprivation, respectively, can modify drug self-administration. Chapters in *Current Status* by Spealman and by Morse, Goldberg, and Katz show dramatically that the behavioral function served by a drug when its administration is a consequence of behavior depends critically (and one might at this time say, mysteriously) on subtle aspects of the contingencies associated with its presentation. Spealman's chapter, for example, presents material indicating that intravenously administered nicotine can serve as a positive reinforcer, a negative reinforcer, or as a punisher depending upon seeming subtleties of the schedule according to which the drug is presented. As noted by Morse et al., "The point is that pharmacological processes are not only changed by environment variables, but that they can be manipulated—accentuated, diminished, and, in a sense, even created" (p. 155).

The chapter by Henningfield (in *Advances*) on the behavioral pharmacology of cigarette smoking deserves special mention. In his remarkably thorough and comprehensive review of the study of cigarette smoking and nicotine self-administration, he carefully outlines the relevant pharmacological and behavioral variables that are known to play a role in cigarette smoking, and shows quite clearly that behavioral variables must play a prominent role in the acquisition and maintenance of this activity. He shows that taking a behavioral perspective on the phenomenon leads to clear thinking about the factors involved. This chapter, because of its conceptual clarity,

as well as its comprehensiveness, should be required reading for all students of drug self-administration, not just those interested in nicotine and cigarettes.

The remaining chapters on self-administration place less emphasis on environmental determination of the reinforcing actions of drugs, and instead focus more heavily on the use of such procedures as models for the study of drug abuse. Two chapters provide a conceptual base for this type of research, those by Thompson (in *Advances*) and by Brady and Fischman. Thompson's chapter is a scholarly treatise on the notion of behavioral mechanisms of drug dependence. In it, he presents a compelling and well-reasoned argument concerning the limits of reductionistic explanation and a thorough analysis of behavioral processes that can be viewed as operating in instances of drug dependence. His general view, and one that I find very attractive, is that a behavioral analysis of drug dependence involves characterizing how the drug interacts with variables that normally influence behavior and how the drug itself takes on the status of a behavioral variable (e.g., as a discriminative or reinforcing stimulus).

Brady and Fischman speak to the use of self-administration (and drug-discrimination) procedures as ways to assess the abuse potential of drugs. They point out that assessment of abuse potential has been one of behavioral pharmacology's major societal contributions. Chapters illustrating the use of self-administration procedures to determine abuse potential include those by Schuster and Johanson and by Griffiths, Roache, Ator, Lamb, and Lukas (both in *Current Status*). Schuster and Johanson review their multifaceted approach to the study of stimulant/anorectic drugs in which they assess appetite suppression, dependence liability (via self-administration and drug discrimination), and neurotoxicity. Griffiths et al. examine the reinforcing and discriminative effects of novel antianxiety agents in an effort to predict the abuse potential of these drugs.

Other chapters in *Current Status* on self-administration include those by

Mello on alcohol, Henningfield and Goldberg on nicotine, and Mendelson and Mello on marijuana. Each of these serves to emphasize the crucial role that the self-administration "model" has come to play in the analysis of drug abuse and drug dependence.

Drug Discrimination

Another field of investigation that is well represented in both volumes is that of drug discrimination. Seven chapters are devoted entirely or in part to descriptions and analyses of drug-discrimination research. These chapters fall into two of the categories outlined earlier; they exemplify the use of behavior-analytic procedures either to answer pharmacological questions or to speak of behavioral functions of drugs as stimuli. Chapters in *Current Status* by Holtzman and by Woods, France, Bertalmio, Gmerek, and Winger illustrate the use of drug-discrimination techniques as pharmacological preparations. Holtzman's chapter is an excellent example of how drug-discrimination techniques are used to help characterize drugs with regard to putative receptor types, and the chapter by Woods et al. demonstrates how drug-discrimination procedures can be used as assays in elegant "receptor protection" designs when studying drug antagonism. The chapters by Schuster and Johanson, by Brady and Fischman, by Griffiths et al., and by Morse et al. mentioned above, also contain information concerning drug discrimination procedures, as does a chapter by Carney, Holloway, Williams, and Seale (in *Current Status*) in which behavioral pharmacological properties of caffeine are examined. In these chapters the emphasis is placed on characterizing the behavioral properties of drugs as discriminative stimuli. The chapters on drug discrimination, then, fall into the last two of the three categories outlined earlier. The role of behavioral *modification* of the discriminative properties of drugs, the kind of research emphasized in the first of our three categories, is a research area that scarcely has been touched (see, however, McMillan & Wenger, 1984).

A noteworthy feature of the chapters on drug-discrimination and drug self-administration is that several of them include information regarding experiments with human subjects. Thus, in a manner that parallels recent developments in the experimental analysis of behavior in general, an increasing number of researchers in behavioral pharmacology are attempting to extend the basic analysis to humans.

Behavioral Toxicology

Another distinguishing characteristic of *Advances* and *Current Status* is that both include chapters that fall into the realm of behavioral toxicology. Behavioral toxicology can be described as a discipline in which behavioral techniques are used to examine effects of compounds that have been defined as toxic according to nonbehavioral criteria. A chapter by Weiss (in *Current Status*) provides the background for the development of the field of behavioral toxicology. He points out that in 1976 Congress mandated that behavior can be used as a standard for judging toxicity, and notes that procedures developed in the experimental analysis of behavior are especially well suited for studying toxic agents. Behavior-analytic procedures yield performances that are stable over long periods of time and, therefore, are ideal for the study of chronic, low-level application of suspected or known toxicants. Behavioral toxicology, then, as a discipline, follows in the tradition of Dews' work by making use of behavior-analytic control techniques, and generally falls into the second category outlined earlier (i.e., interpretations generally consist of descriptions and analyses of how the toxic agents interact with behavioral processes).

Altogether, eight chapters (two in *Advances*, the rest in *Current Status*) are devoted to behavioral toxicology. In addition to the chapter by Weiss, *Current Status* contains chapters by Rice and Cory-Slechta on lead, by Wenger on trialkyl tins, by MacPhail on pesticides, and by Glowa on volatile organic solvents. The two contributions in *Advances* are

by Evans and Daniel and by Cory-Slechta. Evans and Daniel review the use of discriminative behavior as an index of toxicity and provide a clear discussion of the issues involved in using behavior to assess toxicity. Cory-Slechta provides a detailed review of her work on lead, the most thoroughly studied agent in behavioral toxicology. In addition to illustrating many of the technical difficulties involved in the study of a toxicant like lead, Cory-Slechta also provides data illustrating the subtle nature of the kinds of effects lead may have. For example, she presents data suggesting that behavior controlled by differences in brightness may be more susceptible to disruption than is behavior controlled by differences in the shape of visual stimuli.

The appearance of the chapters in both volumes concerning behavioral toxicology indicates that the endeavor should be considered an important and flourishing expansion of the realm of behavioral pharmacology. Behavior-analytic procedures have been identified as especially well suited for investigation of toxic agents, and attempts are being made to characterize the effects in behavioral terms.

Behavioral Drug Effects

The remaining chapters describe the use of behavior-analytic procedures that involve neither self-administration nor drug-discrimination, and are not concerned with toxic agents. With regard to the three categories listed earlier, the papers can be characterized as emphasizing either behavioral actions or pharmacological actions. Those that emphasize behavioral actions include chapters by Emley and Hutchinson (in *Advances*), by Schindler, Gormezano, and Harvey, by Carney, Holloway, Williams and Seale, by Seiden and O'Donnell, and by Fibiger and Phillips (all in *Current Status*). Emley and Hutchinson provide a general overview of the known behavioral effects of nicotine. The papers by Schindler et al. and by Fibiger and Phillips are more analytic. Schindler et al. present data relating to an analysis of drug effects on

respondent conditioning. Their analyses include isolation of the contributions of interactions between drugs and stimulus control by conditional and unconditional stimuli alone, between drugs and motor function, as well as the interaction between drugs and the pairing operations. In conducting such analyses, they have shown that morphine, for example, retards acquisition of a conditional reflex by interacting with the effectiveness of the pairing operations.

Fibiger and Phillips review the status of theories relating to the behavioral action of neuroleptics (drugs used to treat persons labeled as psychotic). Their analyses of available data lead them to suggest that an action common to such drugs is that they retard initiation of operant behavior. This provocative hypothesis should set the occasion for research aimed at examining its generality.

Carney et al. review behavioral effects of caffeine on both uncontrolled performance (e.g., locomotor activity) and behavior controlled by reinforcement schedules, and Seiden and O'Donnell detail their work employing a differential-reinforcement-of-low-rate (DRL) schedule with a long time value (i.e., DRL 78s) as a screening procedure for drugs that will show antidepressant actions. They have found that only drugs that are clinically efficacious in the treatment of depression increase reinforcement rate under their procedure. The search for a behavioral screening technique that is selectively sensitive to antidepressants is a long-standing one. Seiden and O'Donnell's research appears promising.

The remaining two chapters (both in *Current Status*) place more emphasis on pharmacological accounts of drug action. Sepinwall provides an excellent overview of current receptor-based theorizing concerning the action of drugs used to treat anxiety (e.g., diazepam, or Valium), and Guidotti and Ferrero also base their chapter about anxiety-reducing and anxiety-provoking drugs on interpretations based at the drug-receptor level. Both chapters emphasize as well the use of behavior-analytic techniques to engender

well-controlled performances that allow clear interpretation of drug effects.

SUMMING UP

A major purpose of this review has been to determine the extent to which the field of behavioral pharmacology has remained "true" to its origins. It is clear that the texts reviewed indicate that the field has undergone substantial changes, but these changes appear to consist mainly of a broadening of scope. Initially, behavioral pharmacology was a science aimed mainly at the study of environmental determinants of drug action, and was also distinguished by reliance upon methods derived from the experimental analysis of behavior. Subsequently, the field was broadened by inclusion of research directed toward a characterization of drug effects in terms of their interactions with behavioral processes (e.g., stimulus control, conditioned reinforcement, etc.). *Advances* and *Current Status* reveal that the expansion of what constitutes behavioral pharmacology has continued. Most noteworthy are developments in behavioral toxicology and in the use of behavior-analytic methods to answer pharmacological questions. Behavioral pharmacology, today, then is a far broader enterprise than it was at the outset, and its major distinguishing characteristic is the continued employment of and in fact, dependence on, behavior-analytic methods. No longer can the field be viewed as primarily focused on environmental modification of drug effects, but instead now overlaps considerably with the fields of pharmacology and toxicology. It is comforting to see, however, that research in the vital area of environmental/behavioral alteration of drug effects has not disappeared entirely. Research like that described by Barrett (in *Current Status*) illustrates that much (in fact, one might say virtually everything) is left to be done in this vein.

Although not a focus of either this review or of the texts reviewed, the reciprocity that exists between psychology (especially behavior analysis) and behavioral pharmacology is, in several cases,

highlighted by contributions in the two books. Obviously, research in behavior analysis has provided the technical base for behavioral pharmacology, and in those cases where interpretations are couched in terms of interactions between drugs and behavioral processes, it has provided the conceptual base. Less obviously, but just as importantly, research in behavioral pharmacology continues to pose important challenges to conceptual foundations in the study of behavior. Several chapters in the two volumes, like those by Spealman and by Morse et al. in *Current Status* and by Henningfield in *Advances*, provide data that should provoke deep thought about basic behavioral processes and how they are best to be characterized. These chapters reveal that our current views are at best incomplete. Dews, in his introductory comments to *Current Status*, states the case clearly: "Living in the halls of ornate theory, psychology has asked what behavioral pharmacology had to offer in the way of additional embellishment. Behavioral pharmacology is close to earthy reality, so the answer has been, . . . precious little. Indeed heavy footed behavioral pharmacology has caused tremors that have jeopardized the whole filmy fabric of the theories" (p. 4).

Behavioral pharmacology, then, has been and should continue to be an integral part of behavior analysis. The almost overwhelming complexity of drug-behavior interactions serves to make us humble in their face, and serves to encourage us to keep our focus on the real rather than the invented. As Dews also notes in his introduction, "We are currently seeing a 'cognitive' attack to eliminate the salient and to close the frontier of psychology with reality that behavioral pharmacology was breaching" (p. 4). Behavioral pharmacology might profitably be viewed, and utilized, as a spearhead as behavior analysis charges once more into that breach.

REFERENCES

- Barrett, J. E. (1976). Effects of alcohol, chlordinazepoxide, cocaine and pentobarbital on re-

- sponding maintained under fixed-interval schedules of food or shock presentation. *Journal of Pharmacology and Experimental Therapeutics*, 196, 605-615.
- Branch, M. N. (1984). Rate dependency, behavioral mechanisms, and behavioral pharmacology. *Journal of the Experimental Analysis of Behavior*, 42, 511-522.
- Branch, M. N., & Gollub, L. R. (1974). A detailed analysis of the effects of d-amphetamine on behavior under fixed-interval schedules. *Journal of the Experimental Analysis of Behavior*, 21, 519-539.
- Dews, P. B. (1955). Studies on behavior: I. Differential sensitivity to pentobarbital of pecking performance in pigeons depending on the schedule of reward. *Journal of Pharmacology and Experimental Therapeutics*, 113, 393-401.
- Dews, P. B., & Morse, W. H. (1961). Behavioral pharmacology. *Annual Review of Pharmacology*, 1, 145-174.
- France, C. P., Jacobsen, A. E., & Woods, J. H. (1984). Discriminative stimulus effects of reversible and irreversible opiate agonists: morphine, oxymorphone and buprenorphine. *Journal of Pharmacology and Experimental Therapeutics*, 230, 652-657.
- Goldberg, S. R. (1976). The behavioral analysis of drug addiction. In S. D. Glick & J. Goldfarb (Eds.), *Behavioral Pharmacology* (pp. 283-316). St. Louis: C. V. Mosby.
- Gonzalez, F. A., & Byrd, L. D. (1977). Mathematics underlying the rate-dependency hypothesis. *Science*, 195, 546-550.
- Johanson, C. E. (1978). Drugs as reinforcers. In D. E. Blackman & D. J. Sanger (Eds.), *Contemporary research in behavioral pharmacology* (pp. 325-390). New York: Plenum Press.
- Kelleher, R. T., & Morse, W. H. (1968). Determinants of the specificity of behavioral effects of drugs. *Ergebnisse der Physiologie Biologischen Chemie und Experimentellen Pharmakologie*, 60, 1-56.
- McKearney, J. W. (1974). Effects of d-amphetamine, morphine and chlorpromazine on responding under fixed-interval schedules of food presentation or electric shock presentation. *Journal of Pharmacology and Experimental Therapeutics*, 190, 141-153.
- McMillan, D. E., & Wenger, G. R. (1984). Bias of phencyclidine discrimination by the schedule of reinforcement. *Journal of the Experimental Analysis of Behavior*, 42, 51-66.
- Pickens, R. (1977). Behavioral pharmacology: A brief history. In T. Thompson & P. B. Dews (Eds.), *Advances in behavioral pharmacology* (vol. 1, pp. 229-257). New York: Academic Press.
- Schuster, C. R., & Thompson, T. (1969). Self-administration and behavioral dependence on drugs. *Annual Review of Pharmacology*, 9, 483-502.
- Snyder, S. H. (1984). Drug and neurotransmitter receptors in the brain. *Science*, 224, 22-31.
- Stolerman, I. P., & Shine, P. J. (1985). Trends in drug discrimination research analysed with a cross-indexed bibliography, 1982-1983. *Psychopharmacology*, 86, 1-11.
- Thompson, T., & Dews, P. B. (1977). *Advances in behavioral pharmacology* (Vol. 1). New York: Academic Press.
- Thompson, T., & Schuster, C. R. (1968). *Behavioral pharmacology*. Englewood Cliffs, NJ: Prentice Hall.
- Weeks, J. R. (1962). Experimental morphine addiction: method for automatic intravenous injections in unrestrained rats. *Science*, 138, 143-144.
- Young, A. R., & Stephens, K. R. (1984). Antagonism of the discriminative effects of ethylketazocine, cyclazocine, and nalorphine in macaques. *Psychopharmacology*, 84, 336-361.